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(54) Airport surface monitoring and runway incursion warning system

(57) An airport runway incursion warning system (10) for monitoring air and ground traffic at an airport. The system (10) is optimally used with an aircraft (12) that has an electronic tag (21) or interrogation system (21) that stores identification information regarding the aircraft (12), and an RF transponder (22) for receiving interrogation signals and for transmitting the identification information in response thereto. A radar system (41, 20) comprises a plurality of radar sensor units (13) disposed at predetermined installation sites adjacent to a runway (11). Each radar sensor unit (13) typically has an interface processor (42, 14) and telemetry electronics (43, 14a) for communication, although hard-wired communication paths may be used. An RF/telemetry interface (43, 18) is provided for communicating with the radar sensor units (13) when the interface processor (42, 14) and telemetry electronics (43, 14a) are used. The RF/telemetry interface (43, 18) is also used to transmit the interrogation signals to the aircraft (12) and receive the identification information therefrom. A central processing unit (44, 16) is coupled to the radar sensor units (13) for receiving and integrating radar data produced by each the radar sensor units (13) to produce a map of the runway (11) that identifies authorization objects (26) and aircraft (12) that do not constitute intrusion threats, and intruding objects that do constitute intrusion threats to the runway (11). The central processing unit (44, 16) is optionally coupled to the RF/telemetry interface (43, 18) for transmitting signals to and from the aircraft (12), and in this case, the central processing unit (44, 16) processes identification information received from the aircraft (12) to integrate the identification information into to generate a displayed image. An operator display (45, 17) is coupled to the central processing unit (44, 16) for displaying the map and identification information generated thereby for use by an operator.

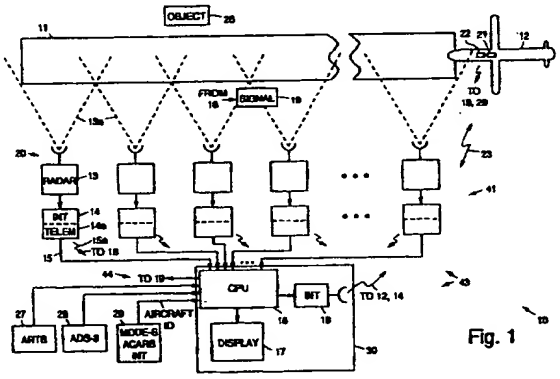

Fig. 1

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Description

BACKGROUND

The present invention relates to radar systems, and more particularly, to a radar system that is used to provide surface monitoring and runway incursion for airports.

The prevention of runaway incursions has been an issue of increasing concern and has resulted in the development of the Airport Surface Detection Equipment (ASDE-3), the Airport Movement Area System (AMASS), and the Airport Surface Traffic Automation Program (ASTA).

The most relevant prior art relating to the present invention, and airport surface monitoring and runway incursion systems in particular is the ASDE-3 radar system which is a single high power Ku-Band real aperture radar that is located on a tower adjacent to an airport. The ASDE-3 system experiences shadowing and multiple reflections that seriously affect the its performance, which is a consequence of the fact that it is a single radar system. The ASDE-3 radar system does not have the ability to interrogate vehicles or aircraft monitored by the system. The ASDE-3 radar system is also relatively expensive.

Therefore, it is an objective of the present invention to provide for an improved radar system that may be used to monitor surface and runway incursion at airports, and the like, and which improves upon the currently-used ASDE-3 radar system.

SUMMARY OF THE INVENTION

In order to meet the above and other objectives, the present invention is a runway incursion warning system for monitoring a runway of an airport and for displaying data indicative of unauthorized intrusion onto the runway to an operator. A radar system is provided that comprises a plurality of radar sensor units that are disposed at predetermined installation sites adjacent to selected runways of the airport. Each radar sensor unit associated with a particular runway generates a radar beam that typically overlaps the adjacent radar beam to provide complete coverage of a runway. Each radar sensor unit is coupled to a collocated interface processor and telemetry electronics that interface between the radar sensor unit and a central processing unit. Communication between each radar sensor unit and the central processing unit may be by physical electrical interconnection and/or RF communication using the telemetry electronics. The physical electrical interconnection may be provided by way of existing cabling normally for runway lights to provide power and the communication link for each of the radar sensor units.

The central processing unit is coupled to an operator display that processed data derived from each of the radar sensor units and displays the data on the operator display. The central processing unit is coupled to an RF/telemetry interface that is used to communicate with the radar sensor units and to aircraft having an electronic tag or transponder system. The central processing unit also integrates and causes the display of data derived from other systems coupled to it, such as the ARTS, ASDE-3, MODE-S or ACARS systems, for example. The central processing unit also generates a display showing the airport runways along with moving and non-moving physical objects that are in the vicinity of the runway. Such objects include departing and arriving aircraft, buildings, and vehicles that are in the vicinity of the runway. Thus, the present system provides a complete display of the runway environment to an operator.

The system may be used with non-cooperative objects or vehicles, or with aircraft or vehicles that have the electronic tag or RF transponder (transmitter and receiver) system. The electronic tag or RF transponder system contains identification information regarding the aircraft, vehicle, or object. The tag or RF transponder receives interrogation signals and transmits the identification information, and other additional information, if desired, in response to the interrogation signals.

The interface processor and telemetry electronics at each radar sensor unit and the RF/telemetry interface provide a communication link between the radar sensor units and the central processing unit. The RF/telemetry interface transmits the interrogation signals and receives the identification information from the aircraft and other cooperative objects or vehicles. Alternatively, the identification information may be received by a central receiver at the airport while the RF/telemetry interface only transmits interrogation signals in conformance with existing aircraft equipment, such as MODE-S or ACARS systems, for example. Multiple interrogation signals sent by different sensor units are separated and identified on the basis of timing, for example, for reception of identifications signals or GPS position information contained in the identification signals themselves.

The telemetry electronics receives data produced by the radar sensor units and the central processing unit integrates the data derived from the radar sensor units and the electronic tag or transponder system in the aircraft. The central processing unit processes data derived from the radar system and identification information received from the electronic tag to produce a map of the airport that identifies authorization objects and aircraft that are not intrusion threats, and intruding objects that are intrusion threats. The operator display displays the map generated by the central processing unit.

The central processing unit generates warning signals in response to intrusion threats that are detected by the system and wherein the warning signals are transmitted to the aircraft by means of the RF/telemetry interface and the RF transponder system. The central processing unit generates an image of the runways that identifies objects, aircraft that are landing and taking off from the runways, and identifying information associ-

ated with interrogated aircraft derived from the electronic tag or transponder system. The central processing unit may also produce data that is displayed on the map that includes priority alert information indicating aircraft that may impose a possible runway incursion, a list of arriving and departing aircraft, and displays that show landing and take-off patterns of arriving and departing aircraft.

The system thus provides for a distributed system of relatively low-cost radars disposed adjacent the runways. Each radar has limited angular coverage and the complete system provides coverage of the entire airport runway area. The present system provides a surface map of aircraft and surface vehicles and point interrogation of aircraft for identification purposes using the electronic tags or transponder system.

The present runway incursion warning system is considerably less expensive than the ASDE-3 radar system, and does not suffer from the shadowing and multiple reflection problems experienced by the ASDE-3 system. The system is scalable to provide monitoring of different size airports. The system provides high range resolution and velocity information, and may be used to interrogate electronic tags or transponder systems disposed on vehicles and aircraft to provide identification information to aircraft traffic controllers that operate the system. The system provides a real-time display of airport surface traffic and warnings of runway incursion.

BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of the present invention may be more readily understood with reference to the following detailed description taken in conjunction with the accompanying drawing, wherein like reference numerals designate like structural elements, and in which:

Fig. 1 illustrates a system block diagram of a runway incursion warning system in accordance with the principles of the present invention; and
Fig. 2 illustrates a typical video display produced by the runway incursion warning system of Fig. 1.

DETAILED DESCRIPTION

Referring to the drawing figure, Fig. 1 illustrates a system block diagram of a runway incursion warning system 10 in accordance with the principles of the present invention. The system 10 includes a radar system 20 that is comprised of a plurality of radar sensor units 13, such as millimeter wave radar sensor units 13, for example, disposed at predetermined installation sites on the ground adjacent to a runway 11, or runways 11, of an airport. Each radar sensor unit 13 associated with a particular runway 11 generates a radar beam 13a that typically overlaps the adjacent radar beam 13a to provide complete coverage of a runway 11, although this is not absolutely required. Each radar sensor unit 13 is coupled to an interface processor (INT) 14 and telemetry electronics (TELEM) 14a that permit communication with a processing center 30 located in an airport control tower, for example. Intelligent processing may be performed at each installation site in the interface processor 14 to reduce the data rate of telemetered data and perform confidence tests. Existing cabling 15 for airport lights provide power and a communication link for each of the plurality of radar sensor units 13, interface processor 14, and telemetry electronics 14a. Alternatively, a dedicated RF communications link 15a may be employed.

A central processing unit (CPU) 16 integrates the data received from the plurality of radar sensor units 13, and maintains a map of authorized targets 26, such as fixed objects 26 or buildings 26 that do not constitute intrusion threats. The central processing unit 16 may also collect input data from an ARTS or ASDE-3 system 27 and available identification reports derived therefrom. The ARTS and ASDE-3 systems provide information regarding aircraft approaching the airport. Data that is derived from an ASDE-3 radar 28, if available, may also be integrated by the central processing unit 16, and a dynamic real-time situation display 17 is provided to an aircraft controller, in graphic format, that is clear and easy to interpret. A sample image on the video display 17 that is presented to an operator of the system 10 is shown in Fig. 2.

The aircraft 12 includes an electronic tag or interrogation system 21 such as a MODE-S or ACARS transponder system 21, for example, that provides identification information regarding the aircraft, and an RF transponder system 22. Warning signals may be transmitted to the aircraft 12 by means of the RF/telemetry interface 18 and the RF transponder system 22 over an RF communications link 23. Warning signals may also be displayed to arriving and departing aircraft 12 using ground signals 19 such as lights or beacons disposed adjacent the runway 11. In addition, the electronic tag or interrogation system 21 may be interrogated by the system 10 using the RF/telemetry interface 18 and the RF transponder system 22. Interrogation signals are transmitted to the aircraft 12 by way of the communication link 23, and the electronic tag or interrogation system 21 on the aircraft 12 responds by outputting information stored therein that is returned to the central processing unit 16 by way of the RF communications link 23.

As shown in Fig. 1, the system 10 is comprised of five major subsystems 41-45. The first subsystem 41 comprises the radar system 20 including the plurality of radar sensor units 13 and electronic components installed at each installation site. The second subsystem 42 comprises the interface processor 14 that is coupled to the radar sensor units 13 and that is located at each remote installation site. The third subsystem 43 comprises a telemetry subsystem and includes the telemetry electronics 14a installed at the installation

sites and an RF/telemetry interface 18 that is coupled to the central processing unit 16 at the central processor site. The fourth subsystem 44 comprises the central processing unit 16. The fifth subsystem 45 comprises the operator display 17 that includes a conventional display and control terminal. Each of the subsystems 41-45 employed in the present invention are well-known and their interconnection and operation is routine to those skilled in the art.

The operator display 17 used in the runway incursion warning system 10 displays information for use by an airport traffic planner or aircraft traffic controller. The data presented on the operator display 17 optimizes the available data while minimizing the need for physical interaction with the system 10. Fig. 2 illustrates a typical video image displayed on the operator display 17 by the runway incursion warning system 10. Referring to Fig. 2, the display 17 shows an image of the runways 11 of the airport and identifies the locations of buildings 26 and other stationary objects 26, aircraft 12 that are landing and taking off from the runways 11, including data 47 from the transponders 21 from interrogated aircraft 12. Typically the data 47 from each transponder system 21 indicates the aircraft number or flight number, as is indicated by the alphanumeric identifiers in the boxes shown on the display 17. Additional data may be displayed including information provided in a system area 51 that provides data regarding the instrument landing system (ILS) system, the time and other relevant system parameters, priority alert information 52 indicating objects 26 or aircraft 12 that are determined to be runway incursions, a list 53 of arriving and departing aircraft 12, and displays 34 that provide real-time images showing the landing and take-off of arriving and departing aircraft 12.

A preliminary proof-of-concept demonstration model of the present system 10 was constructed and data collection was performed at Los Angeles International Airport (LAX) using a test version of a millimeter-wave radar (radar sensor units 13) developed by the assignee of the present invention. Test results show that the system 10 works as expected and provides superior performance over the ASDE-3 radar system.

In summary, there is disclosed an airport runway incursion warning system 10 for monitoring air and ground traffic at an airport. The system 10 is optimally used with an aircraft 12 that has an electronic tag 21 or interrogation system 21 that stores identification information regarding the aircraft 12, and an RF transponder 22 for receiving interrogation signals and for transmitting the identification information in response thereto. A radar system 41, 20 comprises a plurality of radar sensor units 13 disposed at predetermined installation sites adjacent to a runway 11. Each radar sensor unit 13 typically has an interface processor 42, 14 and telemetry electronics 43, 14a for communication, although hard-wired communication paths may be used. An RF/telemetry interface 43, 18 is provided for communicating with the radar sensor units 13 when the interface processor 42, 14 and telemetry electronics 43, 14a are used. The RF/telemetry interface 43, 18 is also used to transmit the interrogation signals to the aircraft 12 and receive the identification information therefrom. A central processing unit 44, 16 is coupled to the radar sensor units 13 for receiving and integrating radar data produced by each the radar sensor units 13 to produce a map of the runway 11 that identifies authorization objects 26 and aircraft 12 that do not constitute intrusion threats, and intruding objects that do constitute intrusion threats to the runway 11. The central processing unit 44, 16 is optionally coupled to the RF/telemetry interface 43, 18 for transmitting signals to and from the aircraft 12, and in this case, the central processing unit 44, 16 processes identification information received from the aircraft 12 to integrate the identification information into to generate a displayed image. An operator display 45, 17 is coupled to the central processing unit 44, 16 for displaying the map and identification information generated thereby for use by an operator.

Thus there has been described a new and improved radar system for providing surface monitoring and runway incursion for airports. It is to be understood that the above-described embodiments are merely illustrative of some of the many specific embodiments that represent applications of the principles of the present invention.

Clearly, numerous and other arrangements can be readily devised by those skilled in the art without departing from the scope of the invention.

Claims

1. An airport runway incursion warning system (10) for monitoring air and ground traffic in the vicinity of a runway (11) of an airport, said system (10) characterized by:

   a radar system (41, 20) comprising of a plurality of radar sensor units (13) disposed at predetermined installation sites adjacent to the runway (11) and wherein the plurality of radar sensor units (13) generate adjacent or substantially overlapping radar beams (13a) that illuminate the runway (11);

   a central processing unit (44, 16) coupled to the plurality of radar sensor units (13), for receiving radar data produced by the plurality of radar sensor units (13), and for processing the radar data to produce a map of the runway (11) that identify objects (26) and aircraft (12) in the vicinity thereof;

   an operator display (45, 17) coupled to the central processing unit (44, 16) for displaying the map of the runway (11), objects (26) and aircraft (12) generated by the central processing unit (44, 16).

2. The system (10) of Claim 1, characterized in that each radar sensor unit (13) is coupled to an interface processor (42, 14) for processing radar data generated by the radar sensor unit (13), wherein

each interface processor (42, 14) is coupled to RF telemetry electronics (43, 14a) for transmitting the radar data to the central processing unit (44, 16), and wherein the central processing unit (44, 16) is coupled to an RF/telemetry interface (43, 18) for receiving the radar data transmitted from the radar sensor unit (13) by the RF telemetry electronics (43, 14a).

3. The system (10) of Claim 2, characterized in that the aircraft (12) comprises an electronic tag (21) that stores identification information regarding the aircraft (12), and comprises an RF transponder (22) coupled to the electronic tag (21) for receiving interrogation signals generated by the central processing unit (44, 16) and for transmitting the identification information in response to the interrogation signals;

and wherein the interrogation signals generated by the central processing unit (44, 16) are transmitted to the aircraft (12) by way of the RF/telemetry interface (43, 18), and the identification information is received from the RF transponder (22) by way of the RF/telemetry interface (43, 18) and wherein the central processing unit (44, 16) generates signals for display on the operator display (45, 17) that identifies the aircraft (12).

4. The system (10) of Claim 2 or 3, characterized in that the central processing unit (44, 16) is coupled to the plurality of radar sensor units (13) by way of a RF communications link (43, 15a) for communicating radar to the central processing unit (44, 16) by way of the RF/telemetry interface (43, 18).

5. The system (10) of any of Claims 1-4, characterized further by an ARTS system (27) coupled to the central processing unit (44, 16), and wherein the central processing unit (44, 16) processes data and identification reports derived from the ARTS system (27) and integrates them into the map that is displayed on the operator display (45, 17).

6. The system (10) of any of Claims 1-5, further characterized by an ASDE-3 radar (28) coupled to the central processing unit (44, 16) and wherein the central processing unit (44, 16) integrates data derived from the ASDE-3 radar (28) into the map that is displayed on the operator display (45, 17).

7. The system (10) of any of Claims 3-6, characterized in that the central processing unit (44, 16) generates an image of the runway (11) that identifies objects (26), aircraft (12) that are landing and taking off from the runway (11), and identifying information (47) associated with interrogated aircraft (12) derived from the transponder (21).

8. The system (10) of any of Claims 3-7, characterized in that the central processing unit (44, 16) produces data for display that includes priority alert information (51) indicating aircraft (12) that are runway incursions, a list (53) of arriving and departing aircraft (12), and displays (54) that show landing and take-off patterns of arriving and departing aircraft (12).

9. The system (10) of any of Claims 3-8, characterized in that the central processing unit (44, 16) generates warning signals (19) in response to intrusion threats that are detected and wherein the warning signals (19) are transmitted to the aircraft (12) by means of the RF/telemetry interface (43, 18) and the RF transponder (22).

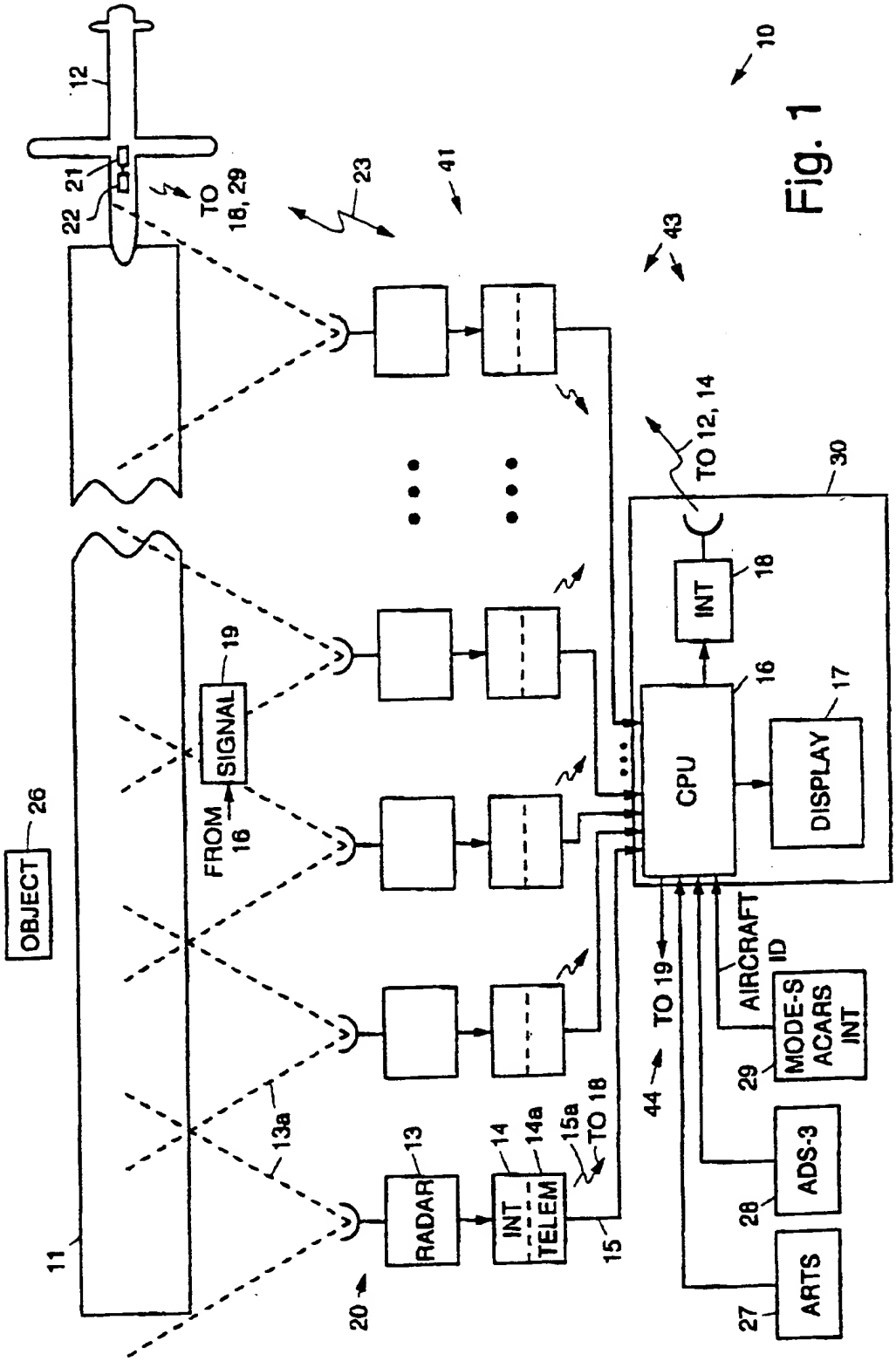
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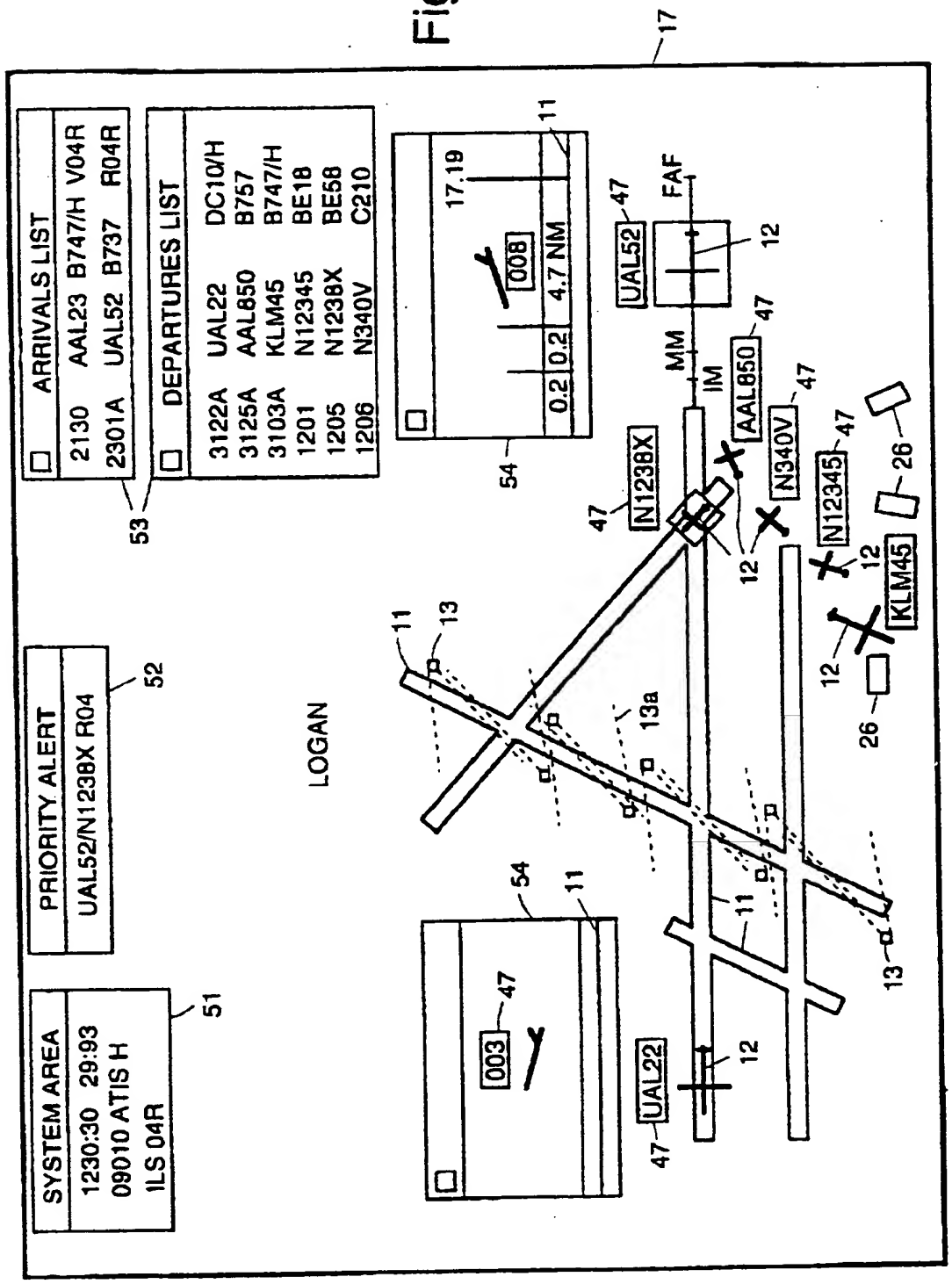
Fig. 1

Fig. 2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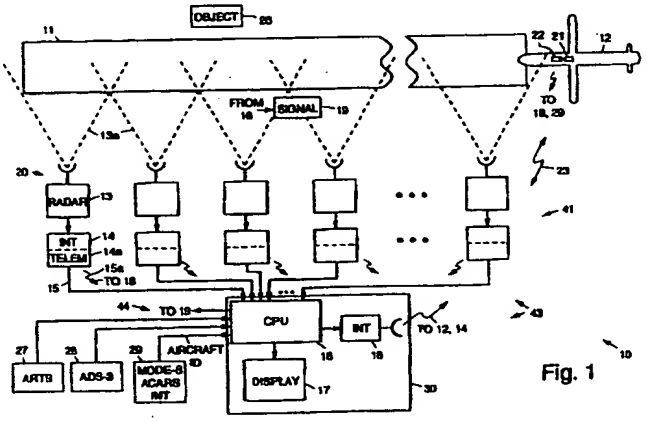

Fig. 1

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EUROPEAN SEARCH REPORT

Application Number
EP 96 10 8293

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	ATUL JAIN: "APPLICATIONS OF MILLIMETER-WAVE RADARS TO AIRPORT SURFACE SURVEILLANCE" DIGITAL AVIONICS SYSTEMS CONFERENCE, PHOENIX, OCT. 30 - NOV. 3, 1994, no. CONF. 13, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, pages 528-533, XP000512920	1-6	G01S13/91 G01S13/93 G01S7/06 G08G5/00 G08G5/06
Y	* page 528, left-hand column - page 531, left-hand column * * page 533, left-hand column - right-hand column; figures *	7-9	
Y	US 5 374 932 A (WYSCHOGROD DANIEL ET AL) 20 December 1994 * column 6 - column 7 * * column 10 - column 34 *	7,8	
Y	GO G ET AL: "ENHANCED AIRPORT SURFACE SURVEILLANCE RADAR" DIGITAL AVIONICS SYSTEMS CONFERENCE, PHOENIX, OCT. 30 - NOV. 3, 1994, no. CONF. 13, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, pages 544-551, XP000512923 * page 550 *	9	TECHNICAL FIELDS SEARCHED (Int.Cl.6) G01S G08G
A	EP 0 220 752 A (DRIM LTD) 6 May 1987 * column 4 - column 9; figures *	1-9	
A	DE 36 40 401 A (SIEMENS) 9 June 1988 * column 11, line 36 - line 51 * * column 2 - column 3 *	1	
A	US 3 872 474 A (LEVINE) 18 March 1975 * abstract; figures *	1	

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	15 October 1997	Devine, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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EUROPEAN SEARCH REPORT

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EP 96 10 8293

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	EP 0 466 239 A (HAAN FRANS HERMAN DE) 15 January 1992		

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

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THE HAGUE	15 October 1997	Devine, J

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L : document cited for other reasons

& : member of the same patent family, corresponding document

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